PATTERNS OF SEED PRODUCTION IN TABLE MOUNTAIN PINE (*PINUS PUNGENS* LAMB.)

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Abstract—The lack of regeneration in stands of Table Mountain pine (*Pinus pungens* Lamb.) in the Southern Appalachian Mountains is of concern, particularly to federal land managers. Efforts to regenerate Table Mountain pine (TMP) stands with prescribed burning have been less successful than expected. Several factors that may play a key role in successful regeneration are currently being investigated. The purpose of this study was to determine if TMP seed viability and availability varied with tree age, cone age, and season. Seeds were collected in four seasons from 2- to 5-year-old cones of 5- to 76+-year-old trees. Results indicate that for trees 11 years and older, cones collected in the winter had the highest number of seeds and the higher percentage of viable seeds. Young trees, less than 10 years old, had many seed, but viability was poor. The results of this study can used to identify stands with an adequate number of viable seed.

INTRODUCTION

Researchers and practitioners have assumed that a seed source is always available in serotinous-coned species such as Table Mountain pine (*Pinus pungens*); however, little is known about the specific seed biology of TMP. Table Mountain pine stands of the Southern Appalachians are fire-dependent. In the past, cultural burning practices and lightning-ignited fires provided the necessary disturbance for maintaining these stands. The implementation of fire suppression programs in the early twentieth century has resulted in a subsequent decline of TMP and a shift toward fire-intolerant species. Since the majority of Southern Appalachian TMP is located on public lands, federal agencies have joined together to regenerate TMP with prescribed burning. However, efforts to regenerate stands with prescribed burning have been less successful than expected (Waldrop & Brose 1999).

The objective of this study was to determine if seed viability and availability vary with tree age, cone age, and season in (TMP). Also, differences in the number of cones per tree were evaluated. Information from this study may be used to identify stands adequate numbers of viable seed in addition to suggesting the most appropriate season for burning.

STUDY AREAS

The first criterion in choosing stands for this study was that TMP be the main component of the stand. Second, several tree age classes ranging from 5 to 75+ years needed to be present. Finally, a sufficient number of closed cones ranging in ages from 2 to 5 years needed to be present on the trees of the various age classes

Several stands in the Nolichucky Ranger District of the Cherokee National Forest (CNF) met the criterion for tree age classes ranging from 11 to 75+ years. Tree age was determined by extracting increment cores at breast height (4.5 ft.) and counting the annual rings.

Additional stands on the Pickens Ranger District of the Sumter National Forest (SNF) and on the Tallulah Ranger District of the Chattahoochee National Forest (ChNF) were needed to provide trees 5 to 10 years of age. In young stands where tree diameter was too small for coring, trees were cut down to determine age.

METHODS

Cone Collection

Cone collection took place in four consecutive seasons, beginning in the fall of 1999 and ending in summer of 2000. One collection was made from each location during each season. Fall months included September, October and November. Subsequent collections for the remaining seasons, winter, spring, and summer included three months for each season.

Sixty-six trees ranging in age from 15 to 148 years (at breast height) were chosen from the three locations in CNF. An aerial lift truck with a 55-foot boom, provided by the U.S.D.A. Forest Service, Southern Research Station, was used for cone collection at the CNF locations.

Forty sample trees ranging in age from 5 to 12 years (at breast height) were chosen from the SNF and ChNF. Access to cones for the younger stands in the SNF and ChNF locations was achieved once trees were cut down.

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Table 1—Average number seeds per cone by tree age class, season, and cone age in TMP stands in the CNF, SNF, and ChNF.

Tree age class	Mean[a]
5 - 10 years	46.0a,b
11 – 25 years	51.9a
26 - 50 years	43.5a,b
51 - 75 years	41.5b
76+ years	37.9b
Season Mean[a]	
Fall	45.9a
Winter	49.8a
Spring	39.2b
Summer	37.5b
Cone age Mean[a]	
2 years	38.2b
3 years	46.0a
4 years	47.3a
5 years	47.0a

[a] Means within each group followed by the same letter do not differ at alpha=.05

A total of 264 cones was expected each season from the 66 sample trees. However, infestations of TMP coneworm(*Diorytria yatesi*) reduced the success of finding sound cones. Collections included only 232 cones (88 percent) in the fall, 206 cones (78 percent) in the winter, 185 cones (70 percent) in the spring, and 160 cones (61 percent) in the summer. Each collection produced increasing evidence of coneworm infestation. There was no sign of coneworm damage in the young sample trees on the Sumter and Chattahoochee National Forests.

This study focused on closed cones 2 to 5 years old. To ensure accuracy, cone age for this study was determined by color, position of whorl on branch, and time of year. In addition, no cones were sampled from broken branches. Once removed from the branch, each cone was placed in a separate paper bag. Tree number, cone age, and location were recorded on the bag.

Seed Extraction

Following cone collection for each season, bags were placed one layer thick in a drying oven for a minimum of 12 hours at 60°C to allow cones to open. Following heating, bags were removed and stored at room temperature. Seeds were removed from the cones, by turning the cones upside down and knocking it on a hard surface. Seeds were collected and seed wings removed. Seeds were then counted, placed in small envelopes, and labeled for identification.

Seed Germination

To determine seed viability, a sample of two-thirds of the total number of seeds extracted from each cone was selected for the germination test. For cones containing fewer than three seeds, one seed was selected. The selected seeds from each cone were placed in a covered 100x15 mm plastic Petri dish lined with a 9.0 cm diameter, course filter paper moistened with deionized water. Petri dishes were labeled, sealed with two-inch parafilm to prevent moisture loss, and placed in an incubator and held at a constant temperature of 25°C for 14 days. After 14 days, dishes were removed and opened. Seeds were considered viable if any growth could be seen.

Statistical Analysis

Each cone collected represented one observation. Percent viability was the number of viable seeds divided by the total number of seeds tested times 100. The total number of seeds extracted from each cone and percent viability per cone was then analyzed with ANOVA using the General Linear Methods procedure in SAS (SAS Institute 1997). Variables tested were tree age-classes, seasons, and cone ages, and interactions among these variables. Means were obtained for tree age-classes, seasons, and cone ages, and tested using Duncan's Multiple-Range test. All statistical analyses were conducted using a 95 percent confidence level.

RESULTS

Seed Availability

Significant differences occurred in the number of seeds extracted from a cone by season and also by cone age (table 1). There were no significant interactions of tree age class, cone age, and season. The average number of seeds per cone generally decreased with tree age class. In general, there were two overlapping groups for tree age class: (1) 11-25 years, 5-10 years and 26-50 years; (2) 26-50 years, 51-75 years and 76+ years. The average number of seeds extracted per cone was significantly higher for the winter and fall collections than for the spring and summer collections. Extraction numbers by cone age indicated that seeds were significantly more numerous in 3-, 4-, and 5-year-old cones than in 2-year-old cones.

Percent Viability

Seed viability significantly varied with tree age classes, seasons, and cone ages. The analysis produced no significance in the interactions of tree age class, cone age, and season. Seed viability was highest for the 76+ years tree age class at 38.6 percent and lowest for the 5–10 year tree age class at 8.8 percent. For the 5-10 year tree age class, seed viability was significantly lower than the other classes. Seed viability for winter and spring collections was significantly higher than viability for fall and summer collections. Viability of seeds collected in the summer was significantly lower than that of the other three seasons. Four and 5-year-old cones did not vary significantly, but had significantly higher viability than did 3- and 2-year-old cones. Viability for 3- and 2-year-old cones did not vary. Four and 5-year-old cones did not vary significantly, but had significantly viability than 3- and 2-year-old cones. Viability for 3- and 2-year-old cones did not vary significantly.

Table 2—Average percent viability of seed by tree age class, season, and cone age in TMP stands in the CNF, SNF, and ChNF.

Tree age class	Mean[a]
5- 10 years	8.8b
11 - 25 years	33.3a
26 - 50 years	32.7a
51 - 75 years	32.9a
76+ years	38.6a
Season	Mean[a]
Fall	28.1b
Winter	40.0a
Spring	35.4a
Summer	
21.2c	
Cone age	Mean[a]
2 years	27.3b
3 years	27.6b
4 years	38.5a
5 years	36.7a

[a] Means within each group followed by the same letter do

DISCUSSION

Lack of regeneration following prescribed fire in the fire-dependent Table Mountain pine stands led to several questions. The questions focused on in this study were, "Can stands with an adequate and viable seed source be identified?" and "Are there differences in seed numbers and viability as a result of tree age, cone age, and/or the season in which the seeds were collected and germinated?"

Seed Numbers and Viability

McIntyre (1929) reported that TMP averaged 49.6 seeds per cone with an average viability of 81 percent. McIntyre (1929) was the only published report with which to compare the results. There was no significant difference in the number of seeds per cone from trees 5 to 76+ years old. However, seeds did decrease in number as tree age increased beginning with the 11-year-old trees. The exception to this trend was the 5- to 10-year-old trees whose seed numbers exceed those trees 26 to 76+ years old. Trees in the 5 to 10 year age class were located farther south in latitude than the 11 to 76+ age class trees, and may have produced differences as a result of soil and climate. McIntyre (1929) found that both drought and heavy precipitation could have a greater influence on cone and seed development than age of tree.

Although trees of all age classes produced an adequate number of seeds, there was a significant drop in percent seed viability and the number of viable seeds per cone in trees 5 to 10 years old. As stated earlier, location may be a factor. This could also be a response to fire intervals in the past. Harmon (1982) and Sutherland and others (1993) showed that prior to acquisition by the U.S. Forest Service, fires occurred approximately every 10 to 12 years in some areas of the Southern Appalachians 1993). Although seed numbers in the 5 to 10 year age class are adequate, low viability in this age class may result in poor regeneration if very young stands are burned too frequently. However, periodic fires are necessary to reduce the establishment of hardwoods which out-compete young seedlings.

Cone Age

The trends for number of seeds per cone and for viability was the same, with 2-year-old cones ranking significantly lower in both categories. Seeds from 3-year-old cones were also significantly lower in percent viability and the number of viable seeds per cone than seeds from the 4- and 5-year-old cones.

This was probably the result of differences in pollenation and other factors in the respective years of cone development. These effects could not be separated because the cones in this study were collected in the same year; that is, 2-year-old cones were initiated in 1998, 3-year-old cones in 1997, and so forth. To separate the effect of cone age from the effect of year would require a multi-year study. This study does suggest, however, that viability does not decrease with time.

Season

Cones collected in winter and fall produced a significantly higher number of seeds than cones from the spring and summer collections. Percent viability was highest in seeds from the winter collection, but not significantly different from spring. The lowest percent viability and the number of viable seeds per cone occurred in seeds in the summer months. This suggests that although cones ripen in autumn of the second season, seed viability may not peak until winter. Mature cones generally turn brown; however, cone color alone may not be sufficient evidence for maturity. To avoid collecting immature seeds, the manual of *Seeds of Woody Plants of North America* (Shopmeyer 1974) suggests checking ripeness in a small sample of cones from individual trees. A mature seed has a firm white or cream-colored endosperm and a yellow to white embryo that nearly fills the endosperm cavity

The delayed effects of severe drought can cause reduced production of viable seed. In addition, high temperatures can cause premature opening of serotinous cones. It also reduces the production of viable seeds by desynchronizing pollen release and female strobilus receptivity or by inhibiting germination (Zobel 1969).

As seeds age, viability can be maintained for some time. However, they eventually enter a period of rapid decline during which some seeds completely fail to germinate and grow normally. The differences in viability among seeds of the same age can be related to heterogeneity of individual seeds within a seed lot (Kozlowski 1972). Frequent fire is an important technique to perpetuate the existence of genetic diversity within stands and would allow for regular population turnover (Gibson and others 1990).

CONCLUSION

To enhance forest health and reduce fuel concentrations, the United States Department of Agriculture and the United States Department of the Interior have established a national program to increase the use of prescribed fire as a management tool. Without periodic fire, it is unlikely that fire-dependent species such as the Table Mountain pine will achieve optimal regeneration.

To achieve success, several factors are needed including adequate seedbed with available moisture and light, fire intervals that do not negatively affect the microbial activity in the soil, and an adequate and viable seed crop. Tree age is not a factor since stands older than 10 years of age provided an adequate seed source.

Although cones did show some difference in their ability to provide adequate viable seed numbers, there would be no way to discriminate among cones of different ages when burning. Further, although the seeds of Table Mountain pine mature in the fall of the second season, winter provided the highest percentage of viable and number of viable seed.

If management of declining populations is to be effective, the development of a prescribed burning plan should consider tree age and season in which burning is implemented to ensure that an adequate and viable seed source is present.

Further investigation into seed biology should be considered. This study was limited to one year and forced to eliminate trees originally selected due to insect damage and drought conditions. Conducting this research over a longer period of time and over a wider area, would better qualify results.

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